

### Effektivare kyl- och värmepumpssystem

#### Sökande

Företag/organisation KTH, Kungliga Tekniska Högskolan		Organisationsnummer 202100-3054		
Institution/avdelning Energiteknik, Avd. Tillämpad Termodynamik och Kylteknik		Postgiro/Bankgiro/Bankkonto PG: 1 56 53-9, BG: 895-9223		
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#### Projektet

<input checked="" type="checkbox"/> Ansökan avser nytt projekt	<input type="checkbox"/> Fortsättning på tidigare projekt, ange projektnummer:
Projekttitel (på svenska) Värmeåtervinning i kylsystem i livsmedelsbutiker, speciellt CO <sub>2</sub> -system	
Projekttitel (på engelska) Investigations of Heat Recovery in Different Refrigeration System Solutions in Supermarket	
Sammanfattning (på svenska). Sammanfattningen skall omfatta max 250 ord och skall skrivas både på svenska och på engelska. Sammanfattningen skall skrivas så att den i ämnet oinvidde med lätthet förstår projektets innehåll och syfte. Korrekt användning av värmepumpande system för att täcka uppvärmning och kylbehov i livsmedelsbutiker kan innebära stora energibesparingar. Då livsmedelsbutiker förbrukar stora mängder elenergi för dessa ändamål är de sammanlagda besparingarna väsentliga. Omsorg om miljön har inneburit stora omställningar för kylindustrin, med bland annat en ökad användning av naturliga köldmedier och ett tydligare fokus på energieffektiva system.  Detta projekt syftar till att undersöka möjligheterna till värmeåtervinning i de nya systemlösningar som introduceras vid installation av naturliga köldmedier, framförallt koldioxid, för livsmedelskyla. Dessa nya system ger nya möjligheter till värmeåtervinning då värme avges från systemen vid flera temperaturnivåer. Maximalt utnyttjande av systemens drivenergi förutsätter därför en modifiering och optimering av systemen, innefattande både deras kalla och varma sida.  Variationerna av kapacitetsbehov och temperaturnivåer över dygnet och över året kommer att klarläggas varefter butikens kyl- och värmebehov vid olika temperaturnivåer kommer att matchas för olika systemlösningar. Sådana lösningar som ger effektiv energianvändning kommer att analyseras ytterligare teoretiskt och experimentellt och jämföras vad gäller effektivitet och investeringskostnad. Fälttester av utvalda installationer kommer att genomföras liksom experimentell utvärdering av nyckelkomponenter i den permanenta testrigg för överkritiska CO <sub>2</sub> system som kommer att byggas på institutionen. Denna kommer att vara en resurs för tillverkare som i denna kan testa olika prototyper av värmeväxlare, kompressorer, expansionsventiler etc.	

Sammanfattning på engelska enligt ovan (max 250 ord).

Proper utilization of the vapour compression system in order to cover the simultaneous needs for cooling and heating in supermarkets is an interesting possibility for major energy savings. This is of special importance given that supermarkets consume lots of energy mainly for the vapour compression system. The environmental concerns and regulations attached to refrigeration applications forced the implementation of new system solutions where natural refrigerants have been widely used and energy efficiency is more of a concern than ever.

This project investigates the heat recovery performance of the new system solutions that are mainly based on natural refrigerants in supermarket refrigeration. The new system solutions with natural refrigerants provide fresh possibilities for heat recovery due to the different temperature levels at which certain heat capacities are rejected. Thus, system modifications and optimizations will take into account not only the cooling efficiency but also the efficient heat recovery according to the needs in the supermarket.

The daily and seasonal profiles of capacity needs with the corresponding temperature levels in the supermarket will be constructed, thereafter; the matching with capacities and temperature profiles of each system solution under investigation will be examined. Accordingly, systems that are identified as good solutions for heat recovery will be further analyzed theoretically and experimentally taking into account the total system efficiency and investment cost.

Field tests of selected installations will be performed and experimental evaluations of key components will be conducted as well as experimental evaluation of key components in the permanent test rig for trans-critical CO<sub>2</sub> systems that will be built at the department. This test rig will be a resource for R&D effort among Swedish heat exchanger manufacturers but also other components such as compressors, expansions valves etc.

Enskilt projekt

Forskningsprogram, ange vilket: EFFSYS 2

Datum för projektstart

080401

Tidpunkt då projektet beräknas vara genomfört

100301

Totalt sökt belopp

933 kkr

Motivering; Energi-/miljö-/näringslivsrelevans, max 250 ord. Ange koppling till resultat från tidigare genomfört program eller projekt.

Supermarkets are intensive energy consumers with constantly increasing number of installations. About 50% of the energy consumption in the supermarket is absorbed by the refrigeration system to cover the cooling demands, simultaneously; heating is needed in the supermarket where the rejected heat from the refrigeration system is usually much higher than the needs. It is an interesting possibility to utilize the rejected heat from the refrigeration system to cover the heating needs in supermarkets.

The environmentally friendly natural refrigerants are seen to be a long term solution in many refrigeration applications as well as in supermarkets. The new solutions provide interesting potential for reclaiming heat from the refrigeration system. Solutions such as parallel, centralized, cascade, direct, indirect, single-, two-, or multiple-stage exist in supermarkets today where each solution will have different temperature levels at which heat is rejected at certain capacities depending on the design of the plant, refrigeration loads, ambient conditions, and the type of compressor.

Previous research conducted at the Energy Technology Department at KTH shows that when comparing cooling efficiencies in supermarkets, solutions which are based on natural refrigerants have great potential in energy savings compared to conventional systems. Additionally, certain systems, such as trans-critical CO<sub>2</sub>, have good heat rejection characteristics with relatively high efficiency when used in the heat pump mode. Therefore, further energy savings are expected from the new system solutions when heat recover is applied.

Previous projects in the area of CO<sub>2</sub> have attracted great interest and several manufacturers express the need for a test facility to test various components in a full system such as heat exchangers, compressor etc. This project will lead to the build-up of a permanent test facility enabling this. Several of the project partners will contribute to the test rig with components as well as assembly and instrumentation.

Bakgrund; vad har gjorts tidigare?, vad är nytt i detta projekt?, forskargruppens verksamhet?, samarbeten? etc, max 1 A4-sida

Some of the heating needs in supermarket systems are for space heating, hot water production, preheating boiler feed water, and defrost water. Each application has specific capacity and temperature level needs which may be matched with heat rejected from refrigeration system in condensation, oil cooling, compressor head cooling in case of reciprocating compressors, high stage de-superheating, condensation, and low stage de-superheating. The later has double benefit due to the heating reclaim and the reduction of cooling load at the high stage compressor. The temperature level and the available heating capacity will depend on the design of the plant, refrigeration loads, ambient conditions, and the type of compressor.

In the "Energy Usage in Supermarkets" project of the previous Effsys program the heat recovery was evaluated versus floating condensing for one conventional system solution. The analysis took into account the heat that is rejected from the condenser only which was used merely for space heating. In this project simulations and field measurements of heat requirements in different supermarkets have been performed where the tool can be used effectively to create daily and seasonal profiles of the space heating needs in the supermarkets.

In another project in the Energy Technology Department the use of CO<sub>2</sub> in supermarket refrigeration has been theoretically and experimentally investigated. Different system solutions has been analyzed including CO<sub>2</sub> in indirect system solutions with R404A, ammonia or propane, two main trans-critical system arrangements have been tested as well as the ammonia/CO<sub>2</sub> cascade system. The analysis took into account only the cooling efficiency of the systems with floating condensing and no heat recovery was considered. The ammonia/CO<sub>2</sub> cascade system shows the highest COP which has up to 60% improvement over a conventional R404A system. A centralized trans-critical CO<sub>2</sub> system shows comparable COP values to conventional R404A system. A simulation tool was developed in this project to simulate the refrigeration systems under investigation where the heat capacity rejected at different temperature levels is calculated depending on the ambient temperatures and refrigeration loads.

The work in this project will be done in close cooperation with Sveriges Energi och Kylcentrum AB (SEK) in order to obtain the field test data. SEK has a running project where field measurements will be carried on to measure the performance of refrigeration systems with natural refrigerants in supermarkets. The data will

be collected to benefit the work in this proposal so the scope of the analysis will be extended to include heat recovery.

This project is seen as complementary to the work being done at the Energy Technology Department and build up on the already established knowledge in the field in the department. The new alternative system solutions will be investigated in the heat pump mode, the heating requirements in the supermarkets will be identified with the required temperature levels and capacities, matching between the sources and needs taking into account the temperature levels will be analyzed. This project provides an overall system prospective of the supermarket in order to make the vapour compression systems energy tighter.

This project proposal has strong connection to two of the running projects in the current Effsys2 program. Similar method of matching the capacity and needs is proposed in "Energy Efficiency in Shopping Centre with an Improved Indoor Climate" project which deals with energy flow in shopping centers. However, in the Shopping Centre project the supermarket system is taken as part of the envelope of the shopping centre whereas in this project the supermarket system is taken as a separate envelope, which is usually the case. This means that the temperature levels, capacities and needs will be different. Investigations in this project will focus on detailed evaluation of different environmentally friendly refrigeration system solutions in order to optimize the system so the maximum amount of heat recovery can be achieved. This project takes closer look at the refrigeration system in the supermarket where the influence of using different types of components, for example different types of compressors, oil cooling and heat storage systems, on the available heat to recover will be investigated.

Experiences gained in heat recovery research and in the estimations for energy consumption reductions are usually based on conventional system solutions. This project focuses on the potential of the new environmentally friendly system solutions. Some systems, such as CO<sub>2</sub>, provide new temperature levels and capacities for heat rejection and may have better matching with the needs in the supermarket. Such potentials of the new system solutions have not been properly investigated yet.

Mål: Ange enkla, tydliga och mätbara mål i exempelvis kWh, max 250 ord.

The objective of this project is to investigate the heat recovery performance of the new refrigeration system solutions in supermarket applications. The focus is on environmentally friendly systems mainly with natural working fluids. The project will analyze the temperature levels and capacities of rejected heat from different system solutions and investigate its matching with the heating needs in supermarkets.

Using simulation tools this project also aims at defining the system solution/s which has good energy efficiency for simultaneous cooling and heat recovery. Thus, system modifications and optimizations will take into account not only the cooling efficiency but also the efficient heat recovery according to the needs in the supermarket. In order to verify the theoretical analysis experimental/field tests are planned for selected systems. Especially needed components will be identified and recommendations for new developments in the field will be given. The cost attached to the application of an efficient heat recovery system will also be addressed.

The findings and knowledge produced in this project will contribute to making the vapour compression system in supermarkets more energy efficient. Studies of new solutions for supermarket systems showed great potential for energy savings when comparing the system only based on the cooling efficiency. However, new heat pump solutions which are based on natural refrigerants, such as CO<sub>2</sub>, ammonia and propane, are promising in some applications. Good heat rejection characteristics of some of the new system solutions suggest that it will have further advantages in energy savings over conventional systems.

In this project, the expected energy savings and the environmental benefits are significant given that supermarkets are intensive energy consumers with large refrigerant charge. The direct and indirect impact on the environment from this application will be considerably minimized.

An explicit goal of the project is to facilitate and support development of CO<sub>2</sub> components and systems

through a well instrumented test rig.



Genomförande, max 250 ord.

The work in this project will be conducted based on the previous knowledge in refrigeration engineering developed at the Energy Technology Department in projects dealing with energy efficiency and alternative refrigeration system solutions in supermarket as well as heat pump applications. Already developed simulation tools and the development of a state-of-the-art experimental test rig will be an important guide and resource in conducting the system analysis but also an important tool for component manufacturers that need to test and evaluate proposed system designs and their components for CO<sub>2</sub> systems. Work in this project will be conducted as follows:

1. Extensive literature survey will be conducted in order to identify what have been done previously in this field and to investigate different methods of approaching the problem
2. Survey will be conducted among major suppliers and consumers in order to define the conventional system solutions and define the heating needs in the supermarket
3. Summary of the system solutions of today for supermarket refrigeration and of the possible new solutions for supermarkets
4. Develop computer models for the calculation of the daily and seasonal capacity and temperature profiles for the supermarket
5. Develop computer models for the calculation of the daily and seasonal capacity and temperature profiles for the rejected heat for different refrigeration system solutions.
6. Define the system solution/s with the lowest energy consumption in simultaneous cooling and heating in the supermarket
7. Theoretically investigate the influence of different parameters on the system performance
8. Modify and optimize the system for the best of its performance fulfilling the cooling and heating needs
9. Analysis of the additional system components needed to produce good heat recovery
10. Building of a permanent well instrumented state-of-the art test rig for CO<sub>2</sub> transcritical refrigeration system in the laboratory
11. Experimentally evaluate selected systems, in the test rig and in field tests, in order to verify the findings of the theoretical analysis
12. Evaluate the installation cost of the developed system

The permanent test-rig is built up at KTH, in the laboratory of Applied Thermodynamics and Refrigeration, The test rig is used in the project to validate computer simulations but it will also be used to evaluate various components such as heat exchangers, compressors, expansion valves and control systems for CO<sub>2</sub> system in close cooperation with the project partners. Different system designs are evaluated to optimally match the heat rejection of the refrigeration system to the various possible heat sinks for best possible efficiency.

Results of the project will be published in local and international conferences and journals. Final report will be produced which will have easy to follow design guidelines.

**Kostnader**

KALENDERÅR	Projektets totala kostnad	Projektets totala kostnader per år			% av heltid
		2008	2009	2010	
Lönekostnader	549000	251401	237679	59920	
Laboratoriekostnad	50000	18750	25000	6250	
Datorkostnad	40000	30000	10000		
Utrustning	900000	700000	150000	50000	
Material	ingår i utrustning	ingår i utrustning	ingår i utrustning	ingår i utrustning	
Resor	50000	25000	25000		
Övriga kostnader	500000	400000	100000		
Ev förvaltningskostnader	242000	90765	120988	30247	
<b>SUMMA</b>	<b>2331000</b>	<b>1515916</b>	<b>668667</b>	<b>146417</b>	

**Finansiering inkl. samfinansiärer**

FINANSIÄR	Andel i kronor och procent av projektets totala kostnader/år				
	År 2008	År 2009	År 2010	Total	%
Energimyndigheten	605916	267084	58000	931000	40.00
AlfaLaval	335000	50000	15000	400000	17.14
Ahlsell	28750	15000	6250	50000	2.14
Nibe	47500	40000	12500	100000	4.29
IVT	47500	40000	12500	100000	4.29
SRM	18750	16583	14667	50000	2.14
Danfoss	155000	40000	5000	200000	8.57
Green and Cool	18750	25000	6250	50000	2.14
RANOTOR	145000	50000	5000	200000	8.57
Climacheck	18750	25000	6250	50000	2.14
ICA Sverige AB	47500	50000	2500	100000	4.29
Hurre Sweden AB	47500	50000	2500	100000	4.29
<b>SUMMA</b>	<b>1515916</b>	<b>668667</b>	<b>146417</b>	<b>2331000</b>	<b>100.0</b>
Detta projekt är <input type="checkbox"/> i sin helhet <input type="checkbox"/> i vissa delar lika med ansökan till annan myndighet, ange vilken: _____					
Sökt stöd för dyr utrustning (Vetenskapsrådet, Wallenbergstiftelsen e.d.) Gäller endast högskola.					

Namn på doktorand	Namn på doktorand
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Övriga samarbetspartners (ange organisation och namn)

Resultatredovisning (ange här om resultatet kommer att redovisas på något ytterligare sätt än det obligatoriska, se information).

Bilagor

Intyg med underskrifter från samfinansierare

Övriga bilagor

Datum 2008-03-10	2008-03-10	Datum
Behörig firmatecknares (prefekt motsv.) underskrift	Projektledarens underskrift	
Namnförtydligande, titel och telefon  Torsten Fransson, prefekt, 790 74 75	Namnförtydligande och titel  Samer Sawalha, PhD student	